

BIRDS AND MAMMALS AS INDICATORS OF THE CONSERVATION STATUS OF TROPICAL FORESTS IN THE ECUADORIAN CHOCÓ

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ABSTRACT

In 2008 and 2009 I surveyed birds and certain mammals using the 'Multi Time-Window Transect-Mapping' (MTW) monitoring protocol sensu Jahn (in press), in order to determine the conservation status of particular sites within the privately-managed Awacachi Biological Corridor, Esmeraldas Province, northwestern Ecuador. Here I focus on the bird data for three (of a total of six) transects, whereas the results for mammals are only considered in order to assess the impact of hunting. The 1200-m transects were located within forest between 50 and 610 m a.s.l. Field work was performed during the rainy season in March and April 2008 (total effort 173.3 h, 20 man-days). With a total of 8049 observations, I detected 226 avian species, including 43 endemics, 17 globally threatened or near-threatened taxa, and 64 species listed in the same threat categories on the national level. Species richness was much higher in the disturbed lowland forest (AWAC1) than in the pristine foothill forest of AWAC3 and AWAC4, with 158, 125, and 124 bird taxa, respectively. However, the remotest and least species-rich transect (AWAC4) had the highest bird community index value ($BCI_{forest} = 2.54$) and also the highest proportions of endemics (24.2 %) and threatened species (world: 8.6 %; Ecuador: 35.5 %). In conclusion, avian species richness by itself is a poor indicator of the conservation value of study sites. Instead, the sites should be ranked on the basis of a detailed comparison of habitat preferences and threat status of their respective bird communities. In addition, the abundance of game species is a good indicator of the impact of hunting at the study sites, with larger mammals, such as *Mazama americana* and *Cebus capucinus*, and some sensitive game birds, viz. *Penelope ortonii*, *Ara ambiguus*, and *Cephalopterus penduliger*, only detected at the remote transects of La Carolina ridge.

Key words: Bird community index, birds, Chocó, conservation status, diversity, Ecuador, endemic species, hunting, Multi Time-window Transect Mapping, species richness, threatened species, threat status value, tropical forest.

INTRODUCTION

Effective and affordable monitoring methods are an important prerequisite for the development of adaptive management strategies for natural resources, the assessment of the status of threatened species, and for studying the impacts of global warming on biodiversity (Jahn 2011). Long-term monitoring programs for at least some biological taxa are particularly important for assessing the success of conservation efforts in species-rich tropical latitudes. In this context, birds score very highly on many objective criteria for the selection of indicators of biodiversity patterns and environmental change (BirdLife International 2004). Although they are obviously not perfect indicators, as no single group of organisms is, many character-

istics make them perhaps the most appropriate biological indicators in tropical habitats (Stotz *et al.* 1996). Birds are well-known in comparison with most other taxa and their populations tend to integrate a number of ecological factors. Consequently, they should always be included as an indicator group in applied conservation-related research and resource management in tropical countries (Jahn 2011).

These were my basic considerations for focusing on bird populations in the present study as well as in previous projects (cf. Jahn 2011). The aim of the present work was to assess whether conservation efforts in the privately-owned Awacachi Biological Corridor, Esmeraldas, northwestern Ecuador, were guaranteeing the survival of threatened, endemic, and

otherwise sensitive wildlife. The study was commissioned by the owner, Fundación SIRUA (www.sirua.org), and by Fauna & Flora International (FFI), who co-manage the nature reserve. Due to the fact that illegal hunting by local people is still an important factor in the slow stabilization and recovery of the populations of larger animals, I also decided to assess certain mammal species, which could be surveyed together with the birds. However, the status of mammals is here only addressed at a qualitative level in the context of hunting.

STUDY AREA

The biomes of northwestern Ecuador belong to the Chocó biogeographic region, which represents an important center of endemism. According to Stattersfield *et al.* (1998), it covers the length of western Colombia and Ecuador (area: 100 000 km², elevational range: 0–3000 m). In southwestern Ecuador it gradually turns into the dry climatic zones of the Tumbesian region. The Chocó is characterized by one of the wettest and most non-seasonal climates on earth. The enormous annual precipitation supports one of the richest forest biotas in the world, with exceptional levels of endemism in a wide range of taxa including plants (Gentry 1986), butterflies (Dinerstein *et al.* 1995), reptiles and amphibians (Lynch 1979), and birds (Terborgh & Winter 1983, Stattersfield *et al.* 1998). Not surprisingly, the Chocó region is part of one of the earth's 25 'hotspots' of biodiversity that are urgent priorities for biological conservation efforts – the Chocó-Darién-Western Ecuador hotspot (Myers 1988, Myers *et al.* 2000). Unfortunately, the region is increasingly threatened by human activities. In the Ecuadorian Chocó forest loss has accelerated to alarming rates since two important road projects were finished in the mid-1990s (Ibarra – San Lorenzo and Esmeraldas – Mataje); see Jahn (in press) for details.

My study area in Esmeraldas, the 10 200-ha Awacachi Corridor (c. 60–650 m a.s.l.), interconnects two of the largest remnants of Chocoan forest in Ecuador, the 'Awá Reserve' and the Cotacachi-Cayapas Ecological Reserve. The latter is the most important protected area in the region (243 638 ha, 80–4900 m; Esmeraldas, Imbabura) (IUCN 1992, INEFAN-GEF 1998, MAE 2007). Although uninhabited, it has in recent years suffered from increased human activities like illegal hunting, logging, and invasions (Jahn *et al.* 2007). The indigenous territory 'Awá Reserve' (101 000 ha; Esmeraldas, Carchi, Imbabura) is not a nature reserve, but was established to maintain the traditional culture of the indigenous Awá people. Hence, the area is inhabited and subsistence agriculture, hunting, selective logging, and even the establishment of oil palm plantations are common and legal (Jahn 2011). Together, these reserves form a forest corridor of about 350 000 ha, extending from the lowlands up to at least 3400 m a.s.l., with páramo grasslands replacing woody vegetation above that altitude. Including migrants and vagrants, the potential number of bird species frequenting the entire area is estimated at more than 750, of which over 600 were already recorded, including 54 species of Neotropical migrants (Jahn 2007). In the following I provide a brief description of the three transects considered here (cf. Table 1):

AWAC1, Río Durango – Río Bogotá area. – The transect was located at the westernmost extreme of the Awacachi Corridor, close to the confluence of the Durango and Bogotá rivers. The site was chosen because it represents the lowest elevation (c. 60 m a.s.l.) of the reserve and is affected by the conversion of natural forest into agricultural land, particularly oil palm monocultures, in neighboring areas. Therefore, strong edge effects exist, making it likely that changes in the composition and structure of the plant and animal communities are in progress. The transect area is intersected by several streams and covered by

TABLE 1. Details on the locality and altitude of the three transects surveyed. The altitudes are based on uncorrected GPS measurements.

Transect	Locality	Start		End		Altitude (m)	
		Latitude	Longitude	Latitude	Longitude	Start	End
AWAC1	Río Durango – Río Bogotá	01°05'00.19"N	78°41'28.11"W	01°04'29.97"N	78°41'06.47"W	65	51
AWAC3	La Carolina ridge	00°53'54.2"N	78°39'27.0"W	00°54'10.3"N	78°38'55.6"W	608	599
AWAC4	La Carolina ridge	00°53'54.9"N	78°39'47.7"W	00°53'32.0"N	78°40'21.6"W	551	600

intensively logged young successional forest, containing numerous recent tree-fall gaps and a presumed natural clearing with shrubby vegetation on swampy ground. It is likely that the site originally fell within the tropical wet forest life zone (*sensu* Holdridge 1967), but due to recent climate change, caused mostly by the rapid and ongoing deforestation in the entire region, the current bioclimatic conditions probably rather correspond to the tropical humid (moist) forest life zone.

AWAC3 and AWAC4, 'La Carolina' ridge. – Both transects are located close to the northwestern limits of the Cotacachi-Cayapas Ecological Reserve, at a ridge which divides the watersheds of the Río Negro to the southeast and the Río Wimbí to the northwest. The transects are separated by a distance of c. 625 m in a straight line and are covered by primary forest with natural tree-fall gaps of varying sizes. Forest streams are present only in the close vicinity of AWAC4. The ridge is located in the premontane pluvial forest life zone (*sensu* Holdridge 1967). In the past only a very few trees were felled in the transect areas.

METHODS

Transect establishment and characterization. – The 1200-m transects were marked with conspicuous distance markers, each 25 m apart, on both sides of the paths. Their orientation, inclination, and altitude were measured and the geographic coordinates of the initial and final points determined with GPS (Global Positioning System).

Transect-mapping surveys. – I surveyed the entire bird communities and selected mammals, using the Multi Time-Window Transect-Mapping (MTW) protocol for monitoring studies; cf. Jahn (2011) for

methodological details. This standardized audio-visual method allows the detection of species that have their activity peaks at different periods of the day. All transects were surveyed with a set of 24 samples. In the case of AWAC3 and AWAC4 a total of six samples had to be repeated due to rain. The surveys were carried out from predawn to after-dusk periods, with highest effort during early morning hours. For each sample period the mean observer speed was adapted to the activity level of the birds. For optimal efficiency, transects were sampled on the way out as well as on the way back. AWAC3 and AWAC4 were surveyed alternately between 13 and 25 March and AWAC1 between 12 and 19 April 2008. The survey effort per transect was higher for the Río Durango – Río Bogotá area than at 'La Carolina' ridge (Table 2), due to the considerably higher bird activity and abundance at the former transect. The average survey effort was 57.8 ± 5.1 h, equaling 288.8 ± 25.6 min per 100-m transect section and complete survey. The average observer speed was 12.0 ± 1.1 min per 100 m, corresponding to only half the speed of conventional line transect protocols used in temperate zones (cf. Bibby *et al.* 1992). The total survey effort, including samples that had to be repeated, was 20 man-days.

Digitalization and correction of the data. – The field data were transferred to pre-established Excel spreadsheets with an effort of about 14 days per complete survey. Subsequently, I corrected the data with the help of the original transect-mapping forms and the audio recordings of animal vocalizations made during the surveys. In this stage, misidentifications and digitalization errors were corrected. Furthermore, I indexed the audio recordings by assigning them to the relevant MTW records in the spreadsheets through specific codes. Records of animals that

TABLE 2. Survey effort and average observer speeds at transects AWAC1, AWAC3, and AWAC4. Abbreviations used: M1A = transect-mapping sample M1A; A2B = transect-mapping sample A2B (cf. Jahn 2011); N_{samples} = number of valid samples carried out.

Transect / Survey	Samples	N_{samples}	Transect length (m)	Effort (h)	Average observer speed (min/100 m)
AWAC1 / 01	M1A – A2B	24	1200	63.6	13.2
AWAC3 / 01	M1A – A2B	24	1200	53.8	11.2
AWAC4 / 01	M1A – A2B	24	1200	55.9	11.6
Sum		72	3600	173.3	36.1
Average		24	1200	57.8	12.0
Standard deviation		0.0	0.0	5.2	1.1

were overlooked in the field but documented in the audio recordings were also added to the data and clearly marked. This procedure is very laborious, but necessary to guarantee the quality and transparency of the information. It took 42 man-days (c. 12-h workdays), corresponding to 14 days per complete survey. Finally, the corrected data were transferred to a georeferenced SQL Server database, with an effort of about five days per complete survey.

Data analysis. – For practical reasons, I follow Ridgely & Greenfield (2001) for avian taxonomy and family and species order. However, I implemented recent gender agreements (David & Gosselin 2002a,b) but not the changes at the level of genera (cf. Banks *et al.* 2003, 2006, 2008). For the determination of endemic species I used Startersfield *et al.* (1998: 199–203, 210–215) and Ridgely & Greenfield (2001: 63–68). For the threat status, I exclusively employed lists based on the official IUCN threat categories (i.e., IUCN 2001, Gärdenfors *et al.* 2001), that is BirdLife International (2009) for the global level and Granizo *et al.* (2002) for the national level. For mammal taxonomy I follow Tirira (2007), and for the global and national threat status of the species I consulted IUCN (2011) and Tirira (1999), respectively.

I used *EstimateS* 6.0b (Colwell 2000) to extrapolate total species richness; cf. Colwell & Coddington (1994), Keating & Quinn (1998), Colwell (2001), and Herzog *et al.* (2002) for discussions and evaluations of these methods, and Jahn (in press) for the richness statistics computed and the settings used. The estimators were determined for the raw data of each complete survey, for pairs of pooled data sets (e.g., 'AWAC3+4'), and for all three transects together. However, at least two samples are required for the calculation of incidence-based estimators, in contrast to abundance-based statistics. As a result, only ACE and Chao 1 could be computed for all data sets.

I have to emphasize that raw transect-mapping data are not 'valid' samples in the sense of statistical models, as they contain repeatedly recorded individuals. However, Jahn (in press) has demonstrated that some species richness statistics may still produce very realistic estimates even with such 'pseudo-abundance' data.

Using *EstimateS* 6.0b (Colwell 2000), I also determined diversity indices Fisher's α , Shannon's H' , and Simpson's D , according to the equations stated in Magurran (1988) and Hayek & Buzas (1996); see

Colwell (2001) for details. However, the information-theory-based diversity statistics, such as Shannon's H' and Simpson's D , have been discredited on many occasions (cf. Magurran (1988) and Jahn (2011) and references therein); therefore, they are shown here only for facilitating comparisons with other studies. For a preliminary comparison of bird diversity between transects, I calculated four similarity indices, two qualitative (incidence-based) indices (Jaccard and Sørensen I) and two quantitative (abundance-based) indices (Sørensen II and Morisita-Horn), according to the equations in Magurran (1988: 95), using *EstimateS* 6.0b (Colwell 2001).

In order to demonstrate how the conservation value of study sites can be assessed by analyzing the composition of their avian communities, I looked at the species' habitat preferences, and at the presence/absence of threatened and endemic bird taxa. The sum of 'threat status values' (sensu Jahn 2011: Table 53) was calculated on the basis of the number of threatened and near-threatened species times an exponentially increasing factor reflecting the severity of the species-specific extinction risks: NT = 1, VU = 3, EN = 9, and CR = 27. In contrast to the $\log_2$ scale proposed by the aforementioned publication, here I used an even stronger gradient ($\log_3$) in order to pronounce the severity of extinction risk in the higher threat categories. Furthermore, I applied the 'bird community index' approach described by Bradford *et al.* (1998) and Canterbury *et al.* (2000), which analyzes the entire avian community as an indicator of forest condition at the local level; cf. Jahn (2011) for details.

RESULTS

General results of the transect-mapping surveys. – In the standardized study of AWAC1, AWAC3, and AWAC4, I mapped 11 401 birds with 8049 observations. They consisted of 42 families, 170 genera, and 226 species (Table 3). Simultaneously with the birds, I made 112 mammal observations with 108 records, belonging to seven families, eight genera, and eight species (Table 4). In the surveys of AWAC1, I recorded 4732 birds with 3441 observations (0.90 records per minute), representing 158 species. At AWAC3, I noted 3472 birds with 2416 observations (0.75 records per minute) of 125 species. The corresponding figures for AWAC4 were 3197 birds, 2192 records (0.65 observations per minute), and 124 species.

TABLE 3. Taxonomic summary of the bird survey results at AWAC1, AWAC3, and AWAC4.

Taxonomic units	Transect			
	AWAC1	AWAC3	AWAC4	All
Families	40	33	34	42
Genera	125	107	103	170
Species	158	125	124	226

TABLE 4. Taxonomic summary of the mammal survey results at AWAC1, AWAC3, and AWAC4.

Taxonomic units	Transect			
	AWAC1	AWAC3	AWAC4	All
Families	2	6	5	7
Genera	3	7	6	8
Species	3	7	6	8

Avian endemics. – A total of 43 endemic bird taxa were detected during the standardized surveys, representing 19.0% of all species observed (Appendix 1). Most of them represent the endemic centers ‘Chocó Lowlands’ and ‘Western Andean Slopes’ sensu Ridgely & Greenfield (2001). The absolute number and proportion of endemics was considerably higher in the foothill zone than in the lowlands (Table 8). At AWAC4 endemic species represented almost a quarter (24.2%; $n = 30$) of the bird community, in comparison with only 12.7% ($n = 20$) at AWAC1. At the latter transect at least three taxa of the ‘Tumbesian Lowlands’ endemics were among the group of range-restricted species.

Threatened bird species. – No less than 17 (7.5%) of the bird species recorded are considered to be either threatened or near-threatened at the global level (BirdLife International 2009), whereas 64 (28.3%) are listed for Ecuador (Granizo *et al.* 2002; Appendix 1). Their numbers were almost identical for AWAC1 and AWAC4, and somewhat lower for AWAC3 (Table 8). However, taking into account the severity of threat, it should be emphasized that globally Endangered species were present only at the foothill transects, viz. *Penelope ortoni* and *Ara ambigua*. Not surprisingly, the threat status values of the latter two transects were higher than those of AWAC1 for both global and national levels. At AWAC3 and AWAC4 I also noted courtship display sites (leks) of *Cephalopterus penduliger* (VU). Two other Vulnerable species, *Micrastur plumbeus* and *Chlorospingus flavovirens*, were exclusively detected at

AWAC4. Furthermore, La Carolina ridge holds the highest population density for *Pittasoma rufopileatum* (NT) of any of the more than 20 study areas which I have surveyed in the Ecuadorian Chocó between 1997 and 2009 (total effort > 500 transect-mapping samples). On the other hand, the transect area of AWAC1 is also of key importance for the conservation of various Vulnerable bird taxa, such as *Ortalis erythroptera*, *Aramides wolfei*, *Capito quinticolor*, and *Dacnis berlepschi*.

Only one globally threatened mammal, the Bush Dog *Speothos venaticus* (VU), was detected (AWAC4). However, this record was exclusively based on tracks crossing the trail (not following it, as would be expected in the case of a domesticated dog, according to local hunters), and thus needs further confirmation. The only primate recorded during the surveys (AWAC3), was the White-throated Capuchin *Cebus capucinus*, listed as Vulnerable at the national level.

Game Species. – The populations of most large mammals and game birds at the survey sites appeared to be depleted or extirpated. The situation was critical in the Río Durango – Río Bogotá area, with only three species of larger mammals detected at low densities. The conditions were considerably better at La Carolina ridge, where populations of some heavily hunted mammals (i.e., *Mazama americana* and *Cebus capucinus*) and some larger species of threatened birds persisted (see previous paragraph). Nevertheless, the lowland site was also an important refuge for some large bird species, particularly raptors ($n = 10$ species), the threatened cracid *Ortalis erythroptera*,

and the heron *Tigrisoma lineatum*. The latter species has been almost extirpated in western Ecuador (Ridgely & Greenfield 2001). As such, the population found in the Awacachi Corridor is of great impor-

tance for the survival of the species in the country's coastal lowlands. *Tinamus major*, another game bird species that quickly disappears in over-hunted areas, was also present in at least two territories at AWAC1.

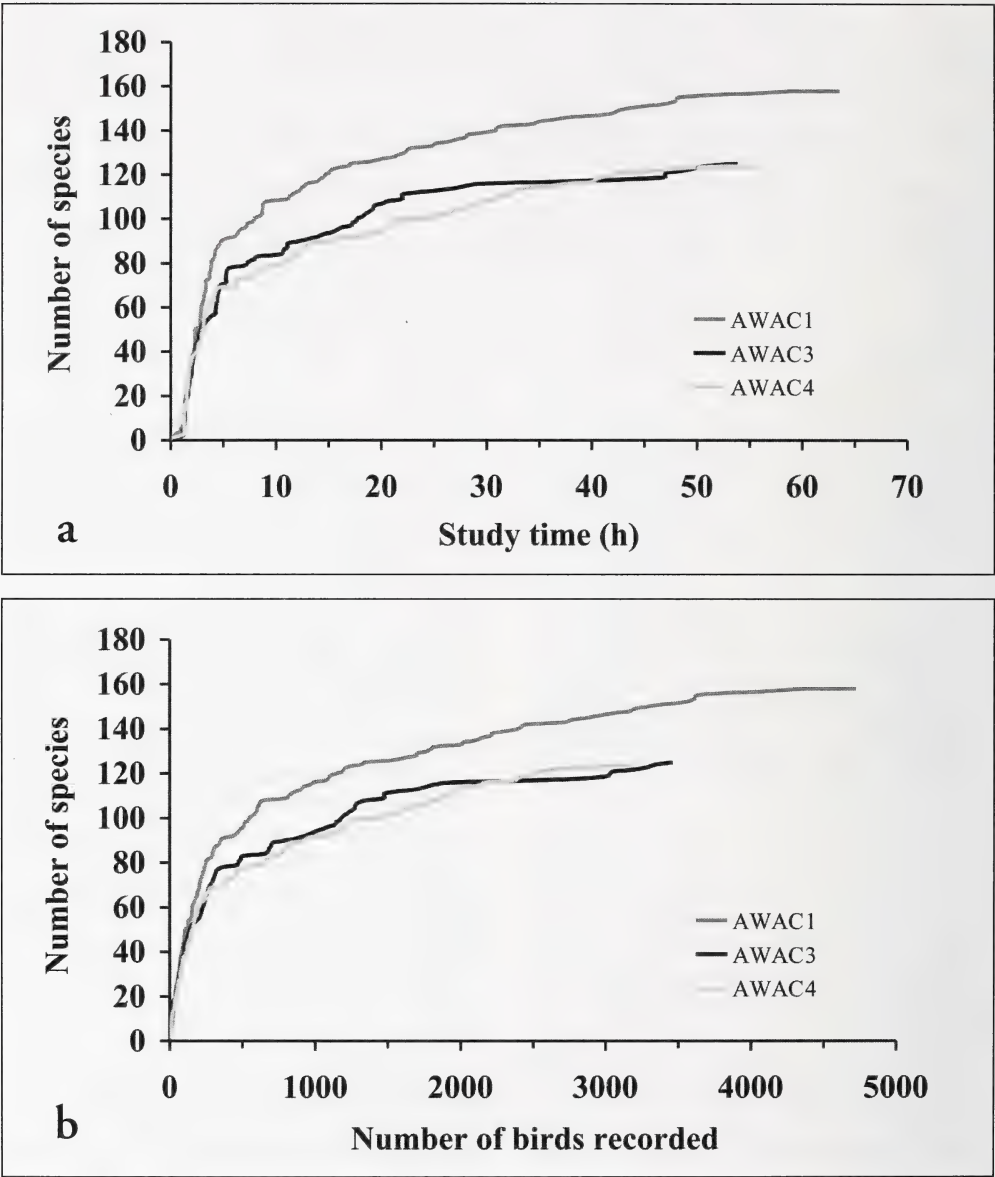


FIG. 1. Comparison of bird species accumulation during standardized transect-mapping (MTW) surveys at transects AWAC1, AWAC3, and AWAC4; (a) number of species versus study time, and (b) number of species versus number of 'birds recorded' (raw data, which include an unknown number of repeatedly observed individuals). AWAC1 represents a disturbed lowland forest in the Río Durango – Río Bogotá area, whereas AWAC3 and AWAC4 were covered by homogeneous primary foothill forest.

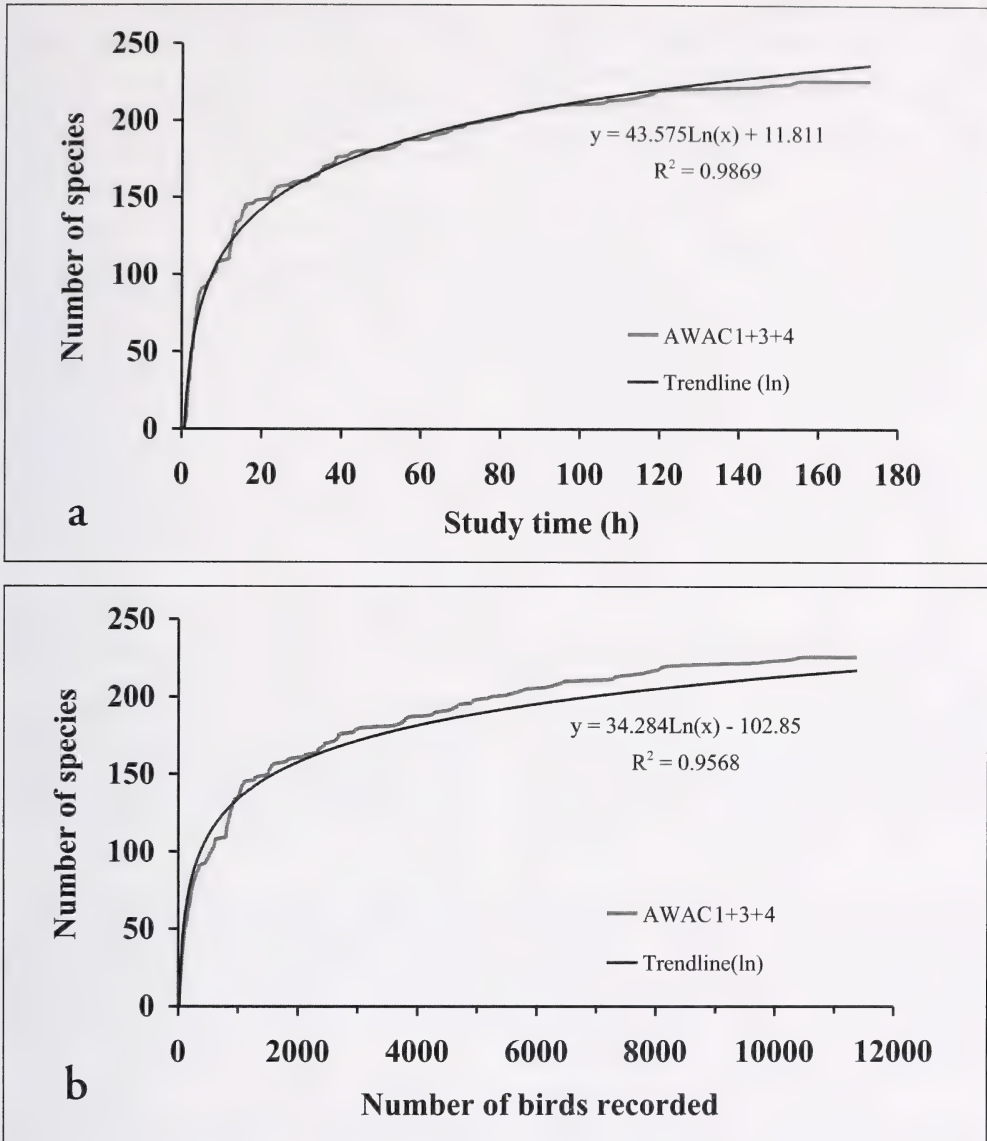


FIG. 2. Bird species accumulation according to the pooled transect-mapping (MTW) data of transects AWAC1, AWAC3, and AWAC4; (a) number of species versus study time, and (b) number of species versus number of 'birds recorded'.

Bird species accumulation. — Species accumulation for the two transects at the Carolina ridge was very similar, with graphs flattening out after about 30–35 h of surveying or 2000–2500 'birds recorded' (Fig. 1a,b). By contrast, at AWAC1 species accumulation continued for about 50 h or 3500 'birds recorded',

reflecting the higher species richness and abundance of the lowland transect. It should be emphasized that the 26% higher species richness at AWAC1, in comparison with AWAC3 and AWAC4, was not the result of the 14% higher survey effort at the former transect, because only two (1.3%) additional species were

detected there in the last 10 survey hours. For the pooled data set of all three transects the graph flattened out after about 120 h or 9000 ‘birds recorded’ (Fig. 2a,b). Lognormal functions fit the species accumulation graphs of transect-mapping data very well, as demonstrated by the high ‘coefficient of determination’ values ($R^2 \geq 0.94$) of all the individual and pooled data sets analyzed (cf. Table 5).

Estimation of total avian species richness. – Species accumulation curves (Figs. 1 and 2) and species richness estimators (Table 5) indicate that the bird surveys were almost complete. According to the higher limits of the Chao1 estimates, I detected between 87 and 93% of all core species (sensu Remsen 1994) present in the transect areas during the survey period. Using the incidence-based statistics MMRuns and MMMean, which require at least two data sets to be computed, the number of core species present at La Carolina ridge can be estimated at 176 bird taxa, of which I detected c. 83% ($n = 146$) during the surveys.

Diversity indices and similarity coefficients. – As expected on the basis of species accumulation graphs (Figs. 1 and 2), diversity index Fisher’s α was very similar for transects AWAC3 and AWAC4 (Tables 6 and 8), although the number of shared species and similarity coefficients indicate that their diversity was not identical (Table 7). By contrast, diversity was

considerably higher in the lowlands than in the foothills and their bird community composition was also very different.

Bird Community Index. – The BCI_{forest} values were highest for transect AWAC4, intermediate for AWAC3, and much lower for AWAC1 (Table 8).

DISCUSSION

Assessment of the conservation status of the transect areas. – According to the standardized transect-mapping surveys, bird species richness and diversity was higher at the lowland transect than in the Carolina-ridge area (Table 8). However, if we look at the habitat selection of the birds, it quickly becomes clear that AWAC1 was more species-rich and diverse only because of the greater extent and variety of disturbed habitats and edge effects there. AWAC3 and AWAC4 held more forest species than AWAC1, whereas the number of forest-edge and open-country taxa was much higher at the latter transect. The disturbed character of the habitats in the Río Durango – Río Bogotá area is clearly reflected by its much lower bird community index (BCI_{forest}) value in comparison with that of the foothill transects. Interestingly, the BCI_{forest} value of AWAC1 was similar to that of two habitat mosaics of semi-open country, forest edges, young successional vegetation, and forest in the Río Santiago floodplain of Playa de Oro ($BCI_{MNTI} =$

TABLE 5. Observed and estimated avian species richness and number of ‘birds recorded’ during standardized transect-mapping surveys at AWAC1, AWAC3, and AWAC4. Abbreviations used: (a) data set: $xy&yz =$ ‘independent’ data sets of the transects; $xy+yz =$ ‘pooled’ data sets; (b) field data: N_{ds} = number of data sets used for the calculation of the species richness estimators; S_{obs} = number of species observed; N_b = number of ‘birds recorded’ (raw MTW data, which include an unknown number of repeatedly observed individuals); (c) species richness estimator: see methods for details.

Data set ^a	Field data ^b			Species richness estimator ^c								
	N _{ds}	S _{obs}	N _b	ACE	ICE	Chao1	Chao2	Jack1	Jack2	Bootstrap	MMRuns	MMMean
AWAC1	1	158	4732	171.6		169.4 ±7.7						
AWAC3	1	125	3472	135.4		136.0 ±8.4						
AWAC4	1	124	3197	131.2		128.7 ±4.3						
AWAC1+3	1	218	8204	234.0		228.1 ±6.2						
AWAC1&3	2	218	8204	234.0	654.6	228.1 ±6.2	394.2 ±39.1	294.5 ±16.5	294.5	256.3	591.5	467.3
AWAC1+4	1	210	7929	222.0		216.4 ±4.5						
AWAC1&4	2	210	7929	222.0	543.5	216.4 ±4.5	339.5 ±29.7	279.0 ±17.0	279.0	244.5	491.7	405.6
AWAC3+4	1	146	6669	154.6		161.1 ±12.2						
AWAC3&4	2	146	6669	154.6	185.5	161.1 ±12.2	154.7 ±4.2	167.5 ±0.5	167.5	156.8	176.5	176.4
AWAC1+3+4	1	226	11401	237.5		236.0 ±6.5						
AWAC1&3&4	3	226	11401	237.5	348.2	236.0 ±6.5	309.7 ±22.1	295.3 ±45.6	319.5	259.2	351.5	336.9

TABLE 6. Diversity indices according to the observed avian species richness and number of birds recorded during standardized transect-mapping surveys at AWAC1, AWAC3, and AWAC4. For AWAC3 and AWAC4 values represent within-habitat α (*alpha*) diversity as these transects were located within homogeneous habitat. In the case of AWAC1 values should be regarded as landscape-level γ (*gamma*) diversity, as this transect was located in a habitat mosaic. Finally, the combined data sets of AWAC1 and the Carolina ridge transects represent regional ϵ (*epsilon*) diversity. Abbreviations used: (a) data set: see Table 5; (b) field data: see Table 5; (c) diversity index: see methods.

Data set ^a	Field data ^b			Diversity index ^c		
	N _{ds}	S _{obs}	N _b	Alpha	Shannon	Simpson
AWAC1	1	158	4732	31.48 ±1.15	4.28	48.56
AWAC3	1	125	3472	25.38 ±1.06	4.01	35.14
AWAC4	1	124	3197	25.66 ±1.09	4.06	38.84
AWAC1+3	1	218	8204	41.13 ±1.23	4.58	63.30
AWAC1&3	2	218	8204	41.13 ±1.23	4.58	63.30
AWAC1+4	1	210	7929	39.59 ±1.21	4.58	64.29
AWAC1&4	2	210	7929	39.59 ±1.21	4.58	64.29
AWAC3+4	1	146	6669	26.37 ±0.94	4.08	37.88
AWAC3&4	2	146	6669	26.37 ±0.94	4.08	37.88
AWAC1+3+4	1	226	11401	39.95 ±1.12	4.56	60.52
AWAC1&3&4	3	226	11401	39.95 ±1.12	4.56	60.52

– 0.049 and $BCI_{MNT2} = 0.541$; Jahn 2011). In the present study, the remotest and least species-rich transect (AWAC4) revealed the highest BCI_{forest} value. The latter transect also had the highest proportion of endemic and threatened species. Although AWAC4’s total number of threatened and near-threatened species was almost identical to that found at AWAC1, its ‘threat status values’ were higher, both on global and national levels. In conclusion, AWAC4 had the highest conservation value of the three transects surveyed. Comparing transects AWAC1 and AWAC3, the latter also had a higher proportion of endemic species and higher threat status values.

However, it should be pointed out that the bird species composition and ecological situation of AWAC1 was so distinct from the foothill transects that they are hardly comparable (Table 7). Taking into account that the Chocoan lowland forests of Ecuador have been almost completely destroyed and that altitudes below 100 m a.s.l. represent only a tiny fraction of the Awacachi Corridor and of other protected areas in the region, then the conservation value of the Río Durango – Río Bogotá area must be regarded as extremely high and its status as critical. The presence of some large and sensitive bird species makes it likely that the hunting pressure has been declining

TABLE 7. Similarity coefficients comparing avian diversity between transects. The quantitative coefficients are based on ‘birds recorded’ during transect-mapping surveys. Abbreviations used: (a) data set: mentioned are the transect codes; (b) field data: S_{obs} = number of species observed in samples 1 and 2; shared S_{obs} 1&2 = number of species shared; (c) shared S_{est} 1&2 = coverage-based estimator for shared species (cf. Colwell 2000); (d) similarity coefficients: see methods for details.

Data set ^a		Field data ^b				Similarity coefficient ^d			
		Shared		Shared	S _{est} 1&2 ^c	(qualitative)		(quantitative)	
1	2	S _{obs} 1	S _{obs} 2			Jaccard	Sørensen I	Sørensen II	Morisita-Horn
AWAC1	AWAC3	158	125	65	73.9	0.30	0.46	0.28	0.32
AWAC1	AWAC4	158	124	72	73.4	0.34	0.51	0.29	0.36
AWAC3	AWAC4	125	124	103	110.6	0.71	0.83	0.79	0.93

there in recent years, making it possible that populations of overhunted mammals (e.g., sloths, monkeys, deer, and peccaries) might also experience a slow comeback in the future. In general, all sites studied in the Awacachi Corridor have the potential to maintain and restore populations of large mammals and birds, whenever hunting can be effectively controlled and the area's forest cover maintained.

Effectiveness and efficiency of transect mapping in bird surveys. – Previous studies demonstrated that Chao1 (and ACE) tend to underestimate true species richness of tropical bird communities (Herzog *et al.* 2002, Jahn 2011). Thus, the high single-survey detection rates found in the present study are not conclusive. However, Jahn (in press) also showed that the incidence-based statistics MMRuns and MMMean produce very accurate estimations when calculations were based on at least two data sets of 24 MTW samples per transect. Similar ecological conditions of the study sites are another important prerequisite for obtaining reliable estimates with so few replicates (see next subchapter). As these conditions were fulfilled for AWAC3 and AWAC4, it seems likely that I really detected over 80 % ($n = 146$) of the total bird species richness present at the Carolina ridge with a survey effort of only 13 man-days (109.7 h). However, additional core species, particularly altitudinal and latitudinal migrants, should be expected to visit the ridge during other months of the year. In consequence, total species-richness estimates are likely to increase with future surveys.

Interestingly, Salaman and co-workers recorded almost the same number of avian taxa ($n = 141$) in a premontane Chocóan forest at Patio (500 m), Junín, Nariño Dept., southwestern Colombia (Salaman 1994). Their survey methods included mist netting and non-systematic observations. However, in comparison with the present work, their study effort in order to accumulate this number of species was 5.4 times higher (70 man-days). For instance, with a mist-netting effort of 44 708 MNH (= Mist-Net Hours), corresponding to a survey period of about two to four weeks, they detected the presence of 80 taxa, or only 55% of the species richness reported in this study. Although other time-efficient bird survey methods do exist, namely the 'random-walk' approach in combination with 5-, 10-, or 20-species lists (Fjeldså 1999, Herzog *et al.* 2002), Jahn (2011) pointed out that the latter method only produces species lists together with rough estimates of relative abundance and total species richness. By

contrast, transect mapping allows the estimation of absolute population densities and biomass with a field effort of approximately one week per transect (Jahn 2011). Furthermore, MTW survey data can be georeferenced with minimal effort, revealing the precise distribution patterns of the birds in the transect areas. However, it must be emphasized that any survey method can only capture the situation at the moment when the samples are carried out. Thus for monitoring purposes it should be taken into account that even in the 'stable' humid tropics the detectability of species and territories fluctuates in time due to various factors (cf. Stutchbury & Morton (2001) and Jahn (2011) and citations therein): (a) lunar cycles (i.e., most nocturnal species are easier recorded during nights around full moon); (b) weather (e.g., poor climatic conditions decrease the detectability of most species); (c) seasonal movements (for their influence on the presence/absence and abundance of migrants); (d) asynchronous breeding (this may cause different territories of the same species to have unequal chances of being detected); and (e) unusual reproduction periods (some synchronous breeding birds tend to reproduce during periods when most other species do not breed). In conclusion, at least two complete MTW monitoring surveys per year and transect should be carried out, one in the rainy season and another in the dry season.

Assessment of the total bird species richness of the Awacachi Biological Corridor. – Evidently it is not possible to estimate the total species richness of the study area with only two transects, even if they represented the ecological extremes of the reserve (i.e., disturbed humid tropical forest vs. primary pluvial premontane forest), like the transect pairs 'AWAC1&3' and 'AWAC1&4' (Table 5). The variance of the richness estimates is clearly too high to be conclusive. This holds true even for the MMRuns and MMMean estimates, which fluctuated between 406 and 592 core species. In contrast to the equal-habitat pair 'AWAC3&4', for which the Michaelis-Menten statistics produced identical estimates ($\Delta = 0.1$ species), the difference for the aforementioned unequal-habitat pairs was very large, with 124 and 86 species, respectively. Interestingly, the difference was much lower when the estimates were based on all three transects together ($\Delta = 15$ species). Assuming that the latter estimates are much closer to reality than those obtained with only two unequal-habitat transects, the total avian diversity of the reserve can be roughly estimated at 337 to 352 core species. Ac-

cording to Jahn (2011), core species represented about 87% of the bird species recorded in Playa de Oro, an intensively studied area, which is located only a few kilometers to the south of the Awacachi Corridor. Thus, the total species richness of the Awacachi Corridor, including non-core taxa (vagrants), can be estimated at c. 387 to 405 bird taxa. However, it is likely that somewhat higher estimates will be obtained when transects from additional life zones (e.g., wet premontane forest) and habitats (e.g., roadside habitats) have been considered in the analysis. All in all, these numbers are very similar to those reported from Playa de Oro, where 344 avian species were recorded up to 2009 and total richness is estimated at > 400 bird species (Jahn 2011).

Animal community characteristics that should be monitored in the long term. – One of the principal objectives of nature reserves is to maintain their biodiversity. Consequently, threatened species are of key importance for monitoring the success of conservation actions. Transect mapping facilitates the effective assessment not only of the presence of red-listed species but also of their absolute population densities (Jahn 2011). Thus, even if the total number of threatened species were to remain stable over certain time periods, changes in their conservation status can still be detected by monitoring their population sizes. ‘Threat status values’ can be used for comparing the importance of particular transects for threatened species and the bird community index (BCI_{forest}) for assessing changes in the sites’ general habitat quality (Table 8). For example, if the forest cover at transect AWAC1 slowly recovered in coming years, its BCI_{forest} values should also increase. Likewise, if local people began to illegally extract timber at ‘La Carolina’ ridge the area’s BCI_{forest} values should decrease considerably, because forest-edge and non-forest species would start to colonize the newly-created gaps and clearings. Finally, changes in hunting pressure can be assessed by observing the presence/absence and population densities of larger mammals and birds.

The number and especially the proportion of endemic taxa should also be monitored. Although past studies have demonstrated that the presence of endemic taxa is a poor predictor for the conservation status of habitat mosaics (Jahn 2011), their proportion of the bird community could still be an important indicator for the status of pristine habitats, given that most range-restricted taxa of the Chocó region are also forest inhabitants. For instance, the

proportion of endemic bird species at La Carolina ridge, particularly AWAC4, might decrease with increasing disturbance. Likewise, at AWAC1, the ratio between Tumbesian and Chocoan endemics could considerably change over time, with ongoing shifts in regional and global climate patterns to drier conditions and more pronounced seasonality of precipitation.

In general, changes in absolute population densities of all species that occur at a sufficient number of transects ($n \geq 4$) and at different densities (avoiding tied ranks in nonparametric tests) should be monitored. In order to facilitate statistical testing of changes in key characteristics of the animal communities, the number of survey units in the Awacachi Corridor should be increased to at least eight transects. Additional transects should be established in the Cotacachi-Cayapas Ecological Reserve and the Awá Reserve to get comparative data on the conservation status of these important remnants of Chocoan forest, which are doubtlessly the main sources for the recolonization of the Awacachi Corridor with locally extinct species, particularly game birds and mammals. In this context, transect mapping might be the best option not only for applying a valid statistical design but also for collecting long-term data for a large number of species (Jahn 2011).

Conclusive remarks on assessing the conservation status of tropical forests. – At the local level, bird species richness and diversity indices are poor predictors of habitat quality and conservation status. Whereas birds that depend on mature forest tend to decrease considerably in number after changes in the forest structure, forest-edge and open-country species might colonize the disturbed habitat. Depending on the biogeographic region or biome, the latter group may mask or outnumber species loss suffered by habitat specialists (Jahn 2011). One important lesson learned from the example presented here is that the conservation value of study sites should be ranked on the basis of a detailed comparison of the habitat selection and threat status of the bird species. The central questions of environmental assessments should not be “How many bird species? / How many individuals?”, but “Which species? / How regular in which habitats and at which sites? / How sensitive in the face of habitat alteration and human disturbance?” and “How threatened at regional and global levels?” (Flade 1994, Jahn 2001). Whenever feasible, the entire bird community should be taken into account, instead of only one or a few indicator species, like

TABLE 8. Assessment of the conservation status of transects AWAC1, AWAC3, and AWAC4, based on transect-mapping data. Number of avian species (N_{spp}) and proportion of total species richness recorded in different classes of main habitats, endemic bird areas, and international threat status categories (IUCN 2001). 'Threat status values', diversity index Fisher's α , and the bird community index (BCI_{forest}) are also stated; see methods for details. Note: some of the taxa listed here as restricted-range species according to Ridgely & Greenfield (2001) were not regarded as endemic species by Stattersfield *et al.* (1998).

Categories	AWAC1		AWAC3		AWAC4	
	N_{spp}	%	N_{spp}	%	N_{spp}	%
Species richness	158	100	125	100	124	100
Main habitat						
- Forest	89	56.3	112	89.6	113	91.1
- Forest edge	41	26.0	13	10.4	8	6.5
- Open country	15	9.5				
- River and stream edges	11	7.0			3	2.4
- No preferences	2	1.3				
IUCN threat status category						
World (BirdLife International 2009)						
- Endangered (EN)			2	1.6	2	1.6
- Vulnerable (VU)	4	2.5	1	0.8	3	2.4
- Near Threatened (NT)	5	3.2	2	1.6	5	4.0
Sum	9	5.7	5	4.0	10	8.1
'Threat status value'	17		23		32	
Ecuador (Granizo <i>et al.</i> 2002)						
- Critically Endangered (CR)			1	0.8	1	0.8
- Endangered (EN)	6	3.8	6	4.8	6	4.8
- Vulnerable (VU)	19	12.0	15	12.0	20	16.1
- Near Threatened (NT)	18	11.4	16	12.8	17	13.7
Sum	43	27.2	38	30.4	44	35.5
'Threat status value'	129		142		158	
Endemic species						
sensu Stattersfield <i>et al.</i> (1998)						
- Chocó	11	7.0	15	12.0	20	16.1
- Tumbesian region	1	0.6				
Sum	12	7.6	15	12.0	20	16.1
sensu Ridgely & Greenfield (2001)						
- Chocó lowlands	17	10.8	14	11.2	18	14.5
- West slope of Andes			12	9.6	12	9.7
- Tumbesian lowlands	3	1.9				
Sum	20	12.7	26	20.8	30	24.2
Ecological indices						
- Fisher's α	31.5 $\pm$ 1.6		25.4 $\pm$ 1.1		25.7 $\pm$ 1.1	
- BCI_{forest}	0.457		2.088		2.539	

flagships and umbrellas, which might be doubtful surrogates for the integrity of ecosystems and the ecological functioning of landscapes (Jahn 2011). Range-restricted taxa and threatened species themselves perform well as indicator groups. Consequently, these species should be integrated into any approach of habitat management and landscape planning procedures. Additional information on the impact of hunting can be obtained by assessing larger mammals together with the birds.

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APPENDIX 1. Endemic and threatened bird species of transects AWAC1, AWAC3, and AWAC4 (n = 80 of 226 species). Abbreviations used: (a) Endemic bird area: Cho1 = Chocó EBA 041 sensu Stattersfield *et al.* (1998); Cho2 = Chocó lowlands (Ridgely & Greenfield 2001); Tum1 = Tumbesian region EBA 045 sensu Stattersfield *et al.* (1998); Tum2 = Tumbesian lowlands (Ridgely & Greenfield 2001); RM2 = Río Marañón valley (Ridgely & Greenfield 2001); wAnd2 = western Andean slope (Ridgely & Greenfield 2001); eAnd2 = eastern Andean slope (Ridgely & Greenfield 2001); (b) Threat status: threat status categories sensu IUCN (2001): NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered; Ecuador = national threat status (Granizo *et al.* 2002); World = global threat status (BirdLife International 2009). Note: some of the taxa listed here as restricted-range species according to Ridgely & Greenfield (2001) were not regarded as endemic species by Stattersfield *et al.* (1998).

Scientific name	Endemic bird area ^a	Threat status ^b		Transect		
		Ecuador	World	AWAC1	AWAC3	AWAC4
<i>Crypturellus berlepschi</i>	Cho1, Cho2	EN			1	1
<i>Leucopternis plumbeus</i>		VU	NT	1	1	1
<i>Leucopternis semiplumbeus</i>		EN		1		
<i>Leucopternis princeps</i>		VU			1	1
<i>Micrastur plumbeus</i>	Cho1, Cho2	EN	VU			1
<i>Ortalis erythroptera</i>	Tum1, Tum2, RM2	VU	VU	1		
<i>Penelope ortoni</i>	Cho1, Cho2	EN	EN		1	1
<i>Odontophorus erythrops</i>		VU		1	1	1
<i>Rhynchortyx cinctus</i>		EN		1	1	1
<i>Aramides wolfei</i>	Cho2	EN	VU	1		
<i>Columba goodsoni</i>	Cho1, Cho2	VU		1	1	1
<i>Leptotila pallida</i>	Cho2			1		
<i>Geotrygon purpurata</i>	Cho2	VU			1	1
<i>Geotrygon veraguensis</i>		EN		1		
<i>Ara ambiguus</i>		CR	EN		1	1
<i>Touit dilectissimus</i>		NT			1	
<i>Pionopsitta pulchra</i>	Cho1, Cho2	VU		1	1	1
<i>Pionus chalcopterus</i>		VU		1	1	1
<i>Amazona autumnalis</i>		EN		1	1	
<i>Otus centralis</i>		NT		1	1	
<i>Glaucidium griseiceps</i>		VU				1
<i>Nyctiphrynus rosenbergi</i>	Cho1, Cho2	VU	NT	1		1
<i>Phaethornis yaruqui</i>	Cho2			1	1	1
<i>Androdon aequatorialis</i>		NT			1	1
<i>Amazilia rosenbergi</i>	Cho1, Cho2			1	1	1
<i>Chalybura urochrysis</i>		VU			1	1
<i>Coeligena wilsoni</i>	Cho1, wAnd2					1
<i>Boissonneaua jardini</i>	Cho1, wAnd2				1	
<i>Trogon comptus</i>	Cho1, Cho2	NT			1	1
<i>Capito squamatus</i>	Cho1, Cho2	NT	NT	1		
<i>Capito quinticolor</i>	Cho1, Cho2	EN	VU	1		
<i>Pteroglossus sanguineus</i>	Cho2	VU		1	1	1
<i>Ramphastos brevis</i>	Cho1, Cho2	VU		1	1	1
<i>Ramphastos swainsonii</i>		VU		1	1	1
<i>Piculus litae</i>	Cho1, Cho2	VU		1		
<i>Celeus loricatus</i>		NT		1	1	1
<i>Veniliornis chocoensis</i>	Cho1, Cho2	VU	NT			1
<i>Campephilus gayaquilensis</i>	Tum2	VU	NT	1		
<i>Hylocistis virgatus</i>		NT		1	1	1
<i>Dendrocolaptes sanctithomae</i>		VU		1		
<i>Xiphorhynchus lachrymosus</i>		VU		1		
<i>Xiphorhynchus erythropygius</i>		NT		1	1	1
<i>Dysithamnus puncticeps</i>		NT			1	1

APPENDIX 1. Continued.

Scientific name	Endemic bird area ^a	Threat status ^b		Transect		
		Ecuador	World	AWAC1	AWAC3	AWAC4
<i>Hylophylax naeviioides</i>		NT		1		
<i>Myrmeciza immaculata</i>		NT		1	1	1
<i>Myrmeciza nigricauda</i>	wAnd2				1	1
<i>Myrmeciza berlepschi</i>	Cho1, Cho2	NT		1		1
<i>Phaenostictus mcleannani</i>		VU		1	1	1
<i>Pittasoma rufopileatum</i>	Cho1, Cho2	VU	NT		1	1
<i>Hylopezus perspicillatus</i>		VU				1
<i>Scytalopus chocoensis</i>	wAnd2	EN			1	1
<i>Rhynchocyclus pacificus</i>	Cho2	NT		1		
<i>Myiophobus phoenicomitra</i>	wAnd2, eAnd2				1	
<i>Contopus cooperi</i>			NT			1
<i>Rhytipterna holerythra</i>		NT		1	1	1
<i>Conopias albobittatus</i>		NT		1		1
<i>Tyrannus niveigularis</i>	Tum2			1		
<i>Lipaugus unirufus</i>		VU			1	1
<i>Cephalopterus penduliger</i>	Cho1, Cho2	EN	VU		1	1
<i>Machaeropterus deliciosus</i>	Cho1, wAnd2				1	1
<i>Thryothorus leucopogon</i>		NT		1	1	1
<i>Cyphorhinus phaeocephalus</i>		NT		1		
<i>Polioptila schistaceigula</i>		VU		1		1
<i>Basileuterus chlorophrys</i>	wAnd2				1	1
<i>Dacnis venusta</i>		NT		1		
<i>Dacnis berlepschi</i>	Cho1, Cho2	VU	VU	1		
<i>Erythrothlypis salmوني</i>	Cho1, wAnd2	NT			1	1
<i>Tangara rufigula</i>	wAnd2				1	1
<i>Tangara palmeri</i>	wAnd2	NT			1	1
<i>Tangara johannae</i>	Cho1, Cho2	VU	NT	1		
<i>Tangara lavinia</i>		NT		1	1	1
<i>Bangsia rothschildi</i>	Cho1, Cho2	VU			1	1
<i>Bangsia edwardsi</i>	Cho1, wAnd2				1	1
<i>Chlorothraupis stolzmanni</i>	wAnd2				1	1
<i>Heterospingus xanthopygius</i>	Cho2	NT		1	1	1
<i>Chlorospingus flavovirens</i>	Cho1, Cho2		VU			1
<i>Chlorophonia flavirostris</i>	Cho1, wAnd2				1	1
<i>Euphonia fulvicrissa</i>		NT		1		
<i>Cacicicus microrhynchus</i>		NT		1	1	1
<i>Zarhynchus wagleri</i>		VU		1		
Total = 80	43	64	17	47	49	56